

Combustion Control of Premixed Swirl Flame Using Additional Injection

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Outline of this Presentation

As for the development of Active Combustion Control system,

□ Motivation

- *motivation of developing the ACC system using additional gas injection method (AGI)*
- *concept of outer injection nozzle array*

□ Prediction of Oscillatory Combustion

- *feature of OH* and CH* chemiluminescence*

□ Performance of Outer Injection

- *feature of controlling pressure fluctuation and emissions*

□ Summary



Philosophy of Combustion Control

Additional Gas Injection (AGI) Method as an Actuation

➡ Synchronization between pressure and heat release fluctuations

Needs on combustion control technology

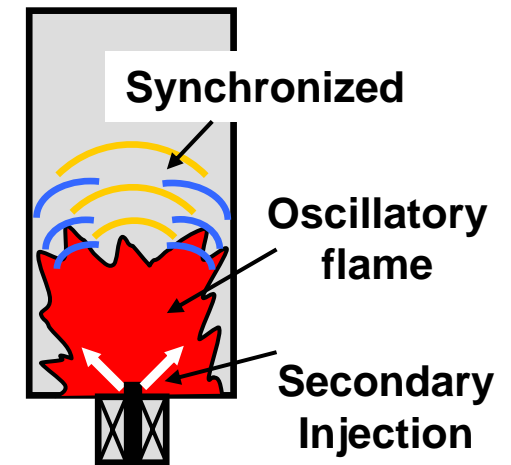
✓ Active Combustion Control (ACC) technology

• What is the benefit to use AGI technology ?

- modulation of the heat release fluctuation (HRF)
 - ➡ improvement on feedback loop, phase shift the HRF
- jet momentum
 - ➡ share effect, disturbance of the HRF

Integration of control theory and AGI actuation

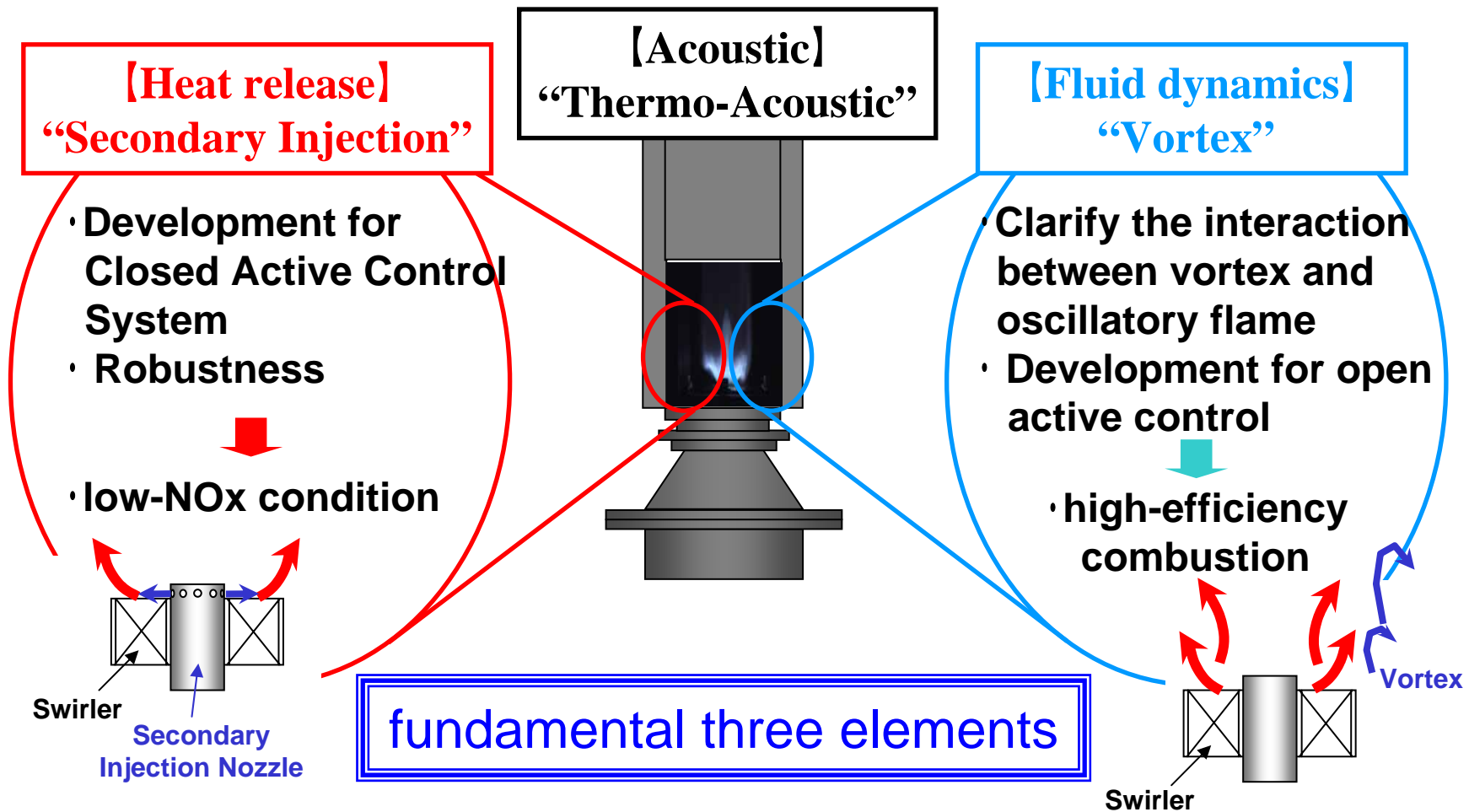
[Image of AGI]



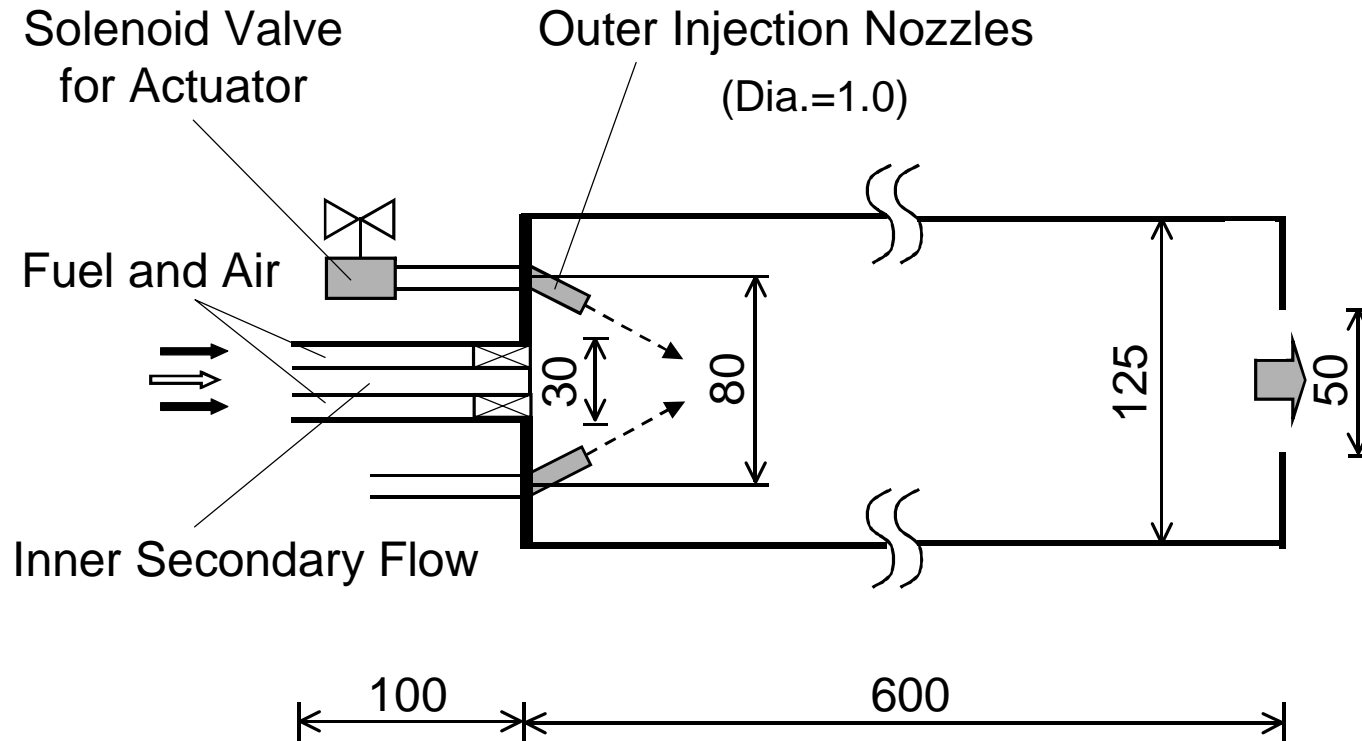
Correlation of Fundamental Factor on ACC

Concept for combustion control

- Acoustics
- Heat release
- Fluid dynamics



Configuration of Test Combustor



- inlet tube is about 100-mm long and its diameter is 30-mm
- combustor is the size of 125-mm square in cross-sectional area, 600-mm long
- swirl stabilized flame holder (swirl angle; 15 deg) is used
- **outer injection nozzles provides additional gas actuation**



Sensor and Actuator

➤ Pressure transducer



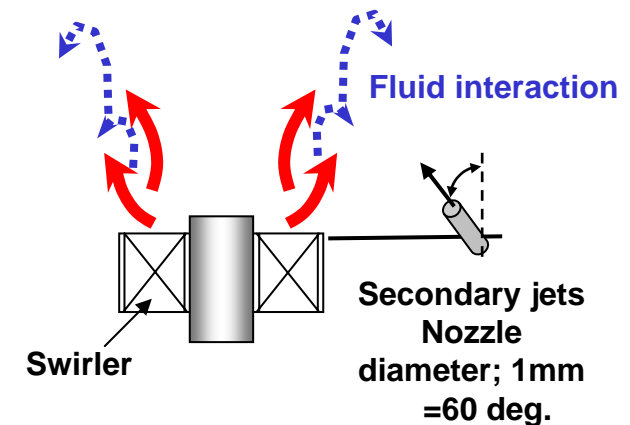
- Piezo-resistive Absolute Pressure Sensor; 4045A KISTLER
- Sensitivity; 2.5-500mV/bar

➤ Optical device



- Si-Photo Diode;
S2281-04 HAMAMATSU
- wavelength; 190-1100 nm

➤ Outer injection (secondary jets)



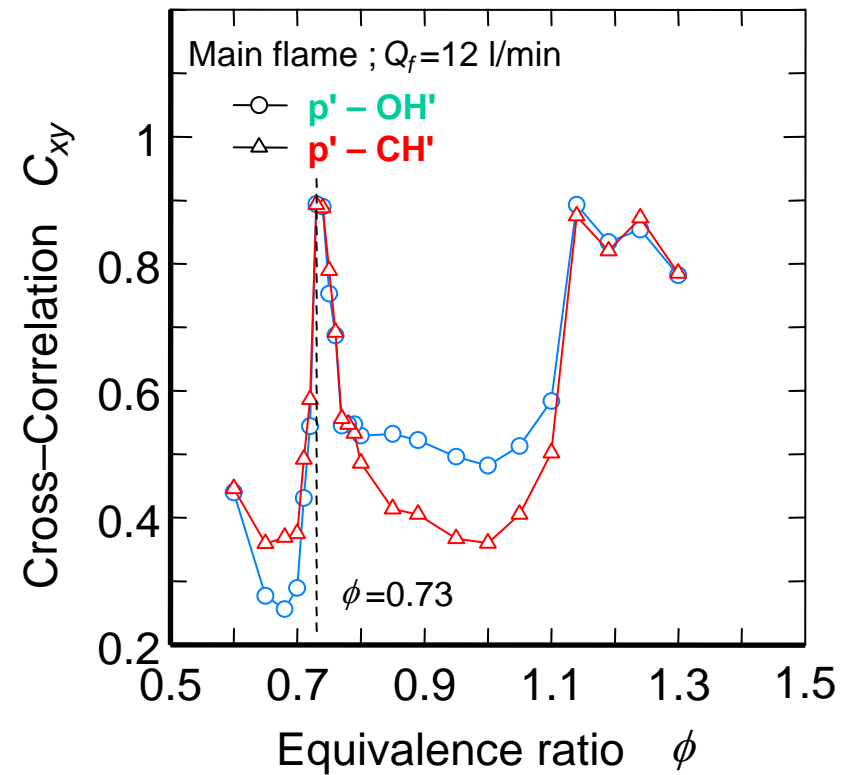
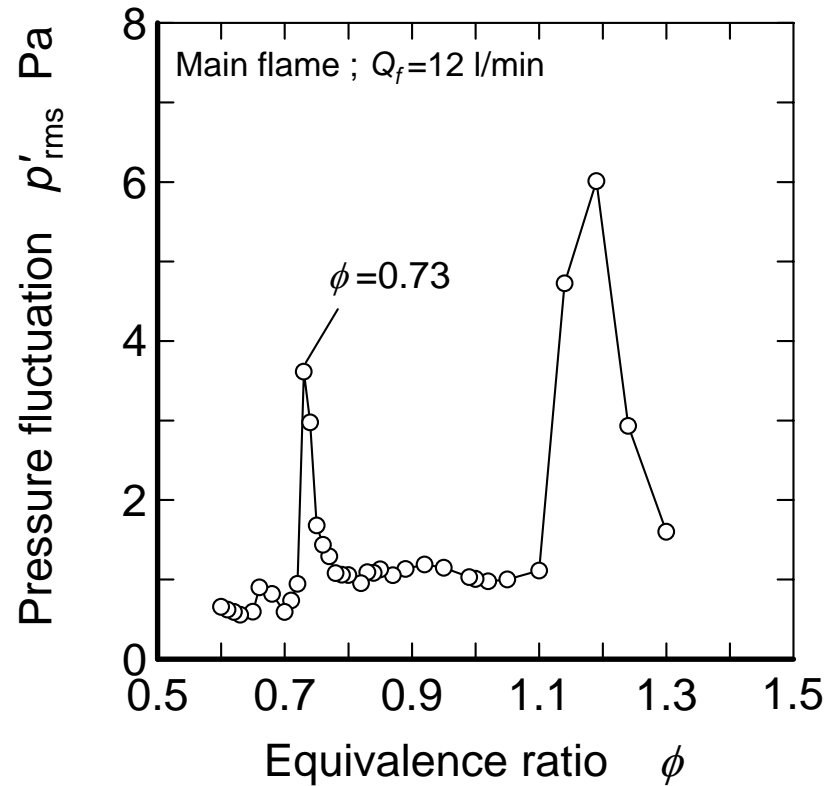
➤ Actuator



- Servo Valve;
58A-262 , HSC Controls Inc.
- frequency; ~ 400 Hz (user checked)



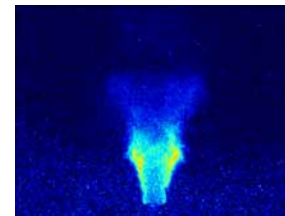
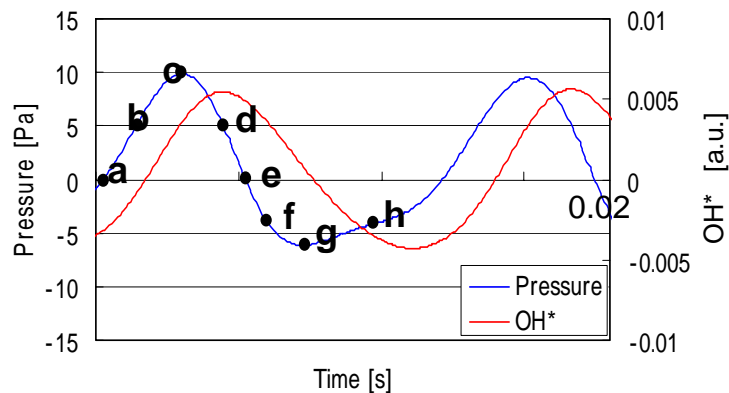
Pressure Transducer and Optical Sensors



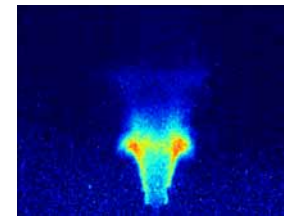
Feature of Oscillatory Flame – OH* chemiluminescence –

Flame conditions;

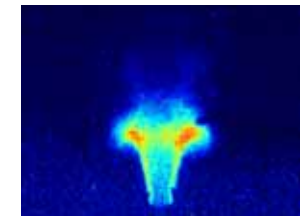
$\phi=0.75$, $Q_f=12$ l/min, $Q_a=152$ l/min
(oscillatory flame)



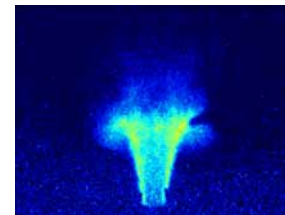
0deg.



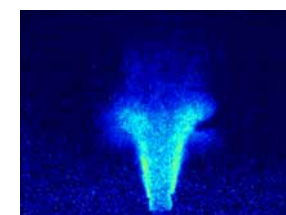
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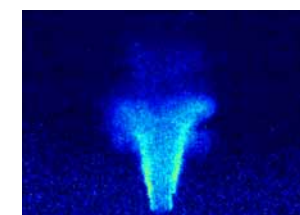
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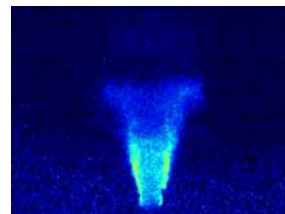
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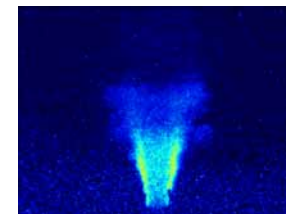
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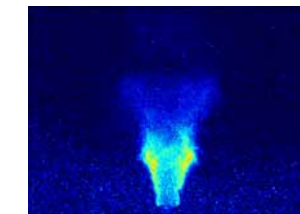
225



270



315



360

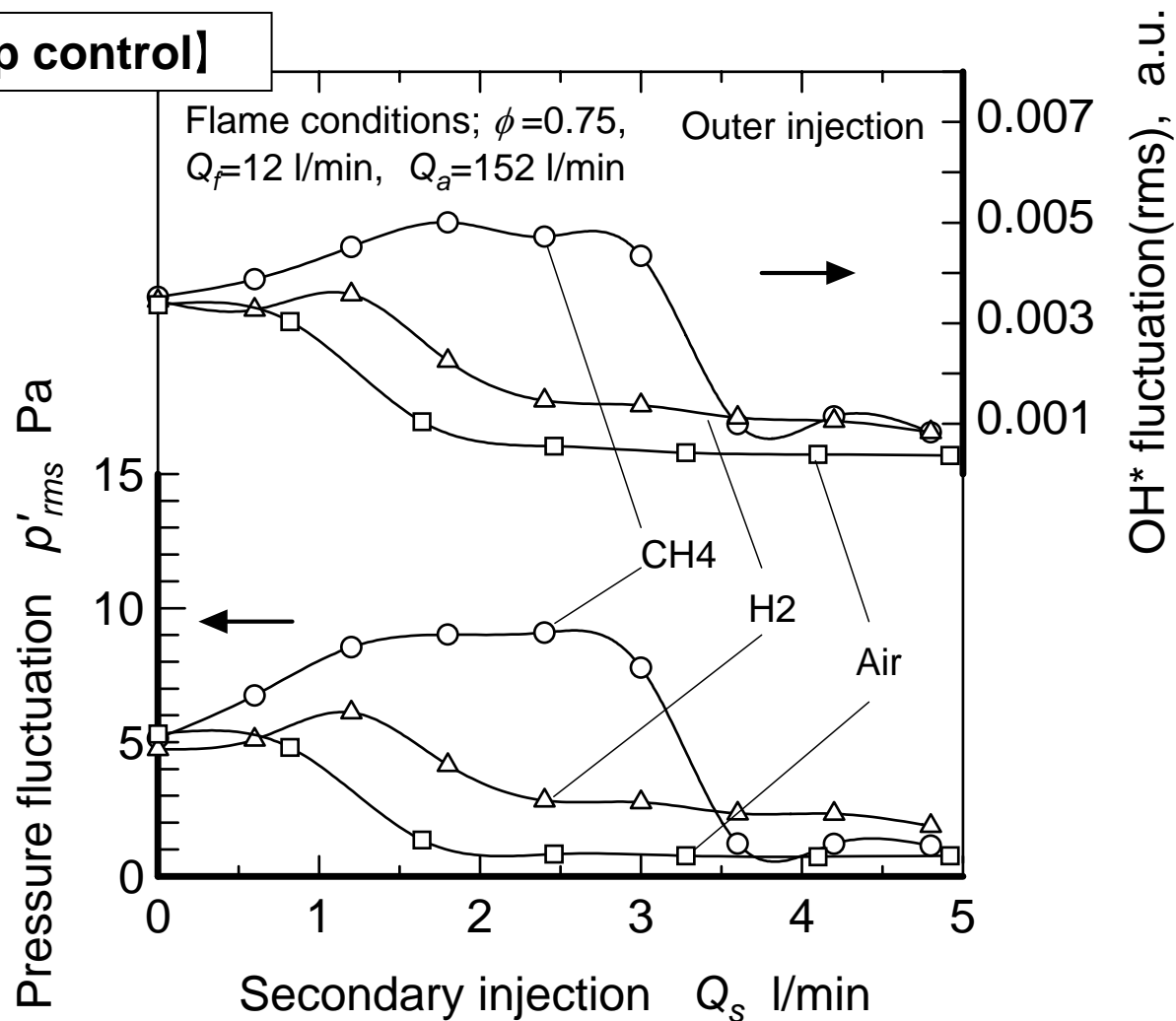
- flame is deformed or fluctuated due to the flow field of recirculation zone
- heat release fluctuation will be strong at the flame top in which intensive deformation occurs
- disturbance of the recirculation flow seems to be effective actuation for ACC



Additional Injection from Outer Equipped Nozzles

What is the benefit ?

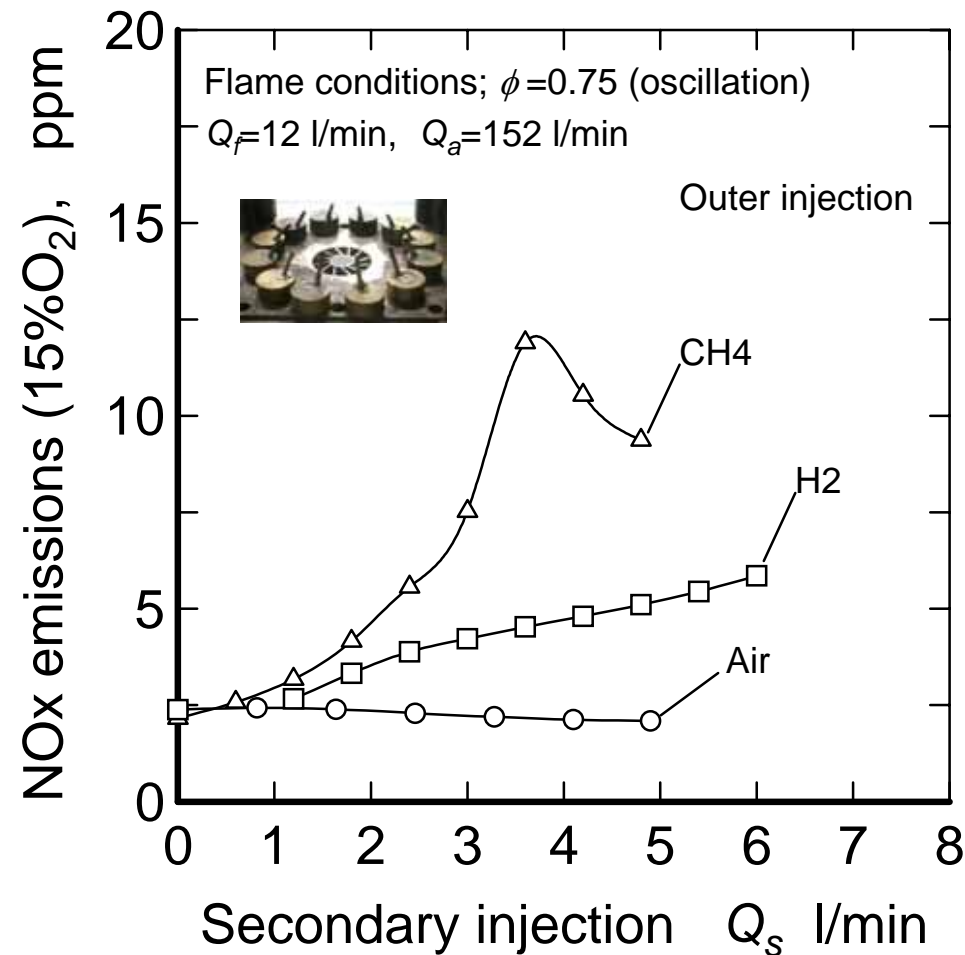
[Open-loop control]



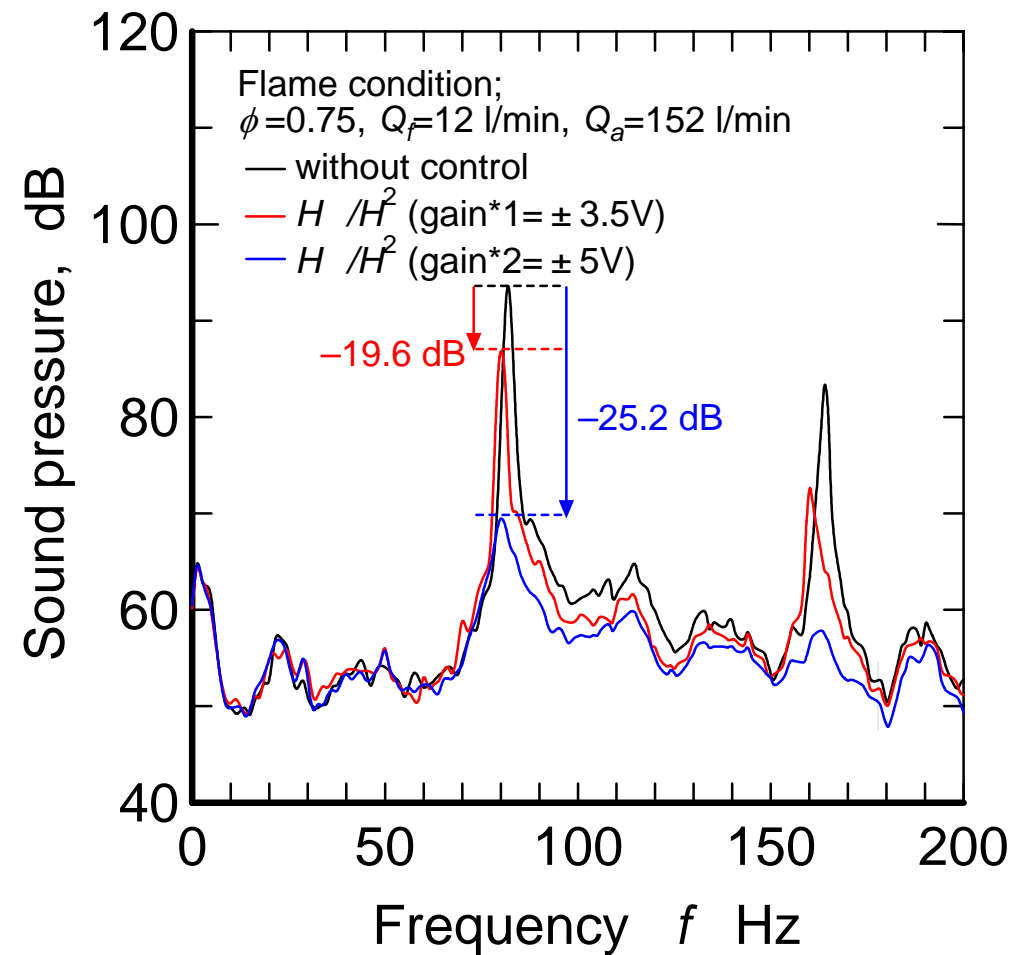
Emission Suppression

What is the effective gas for additional injection?

[Open-loop control]



Comparison between Open- and Closed-Control



Summary

In this study, a mixed H^2/H controller for a practical active combustion control system was developed to control flame stability and emissions.

The results are the follows:

1. Additional air-jet injected from outer of the swirl-type flame holder was one of the effective actuation for ACC. The actuated air-jet suppressed the pressure fluctuation and NOx emissions.
2. The hybrid controller is adopted for the robustness and good performance. The H algorithm is expected to guarantee the robustness against modeling error, and the H^2 algorithm was expected to achieve good performance.
3. The developed ACC system with the mixed H^2/H controller indicated a good performance to suppress the strong pressure fluctuation with the result of 25dB reduction (from 91 dB to 66 dB).

